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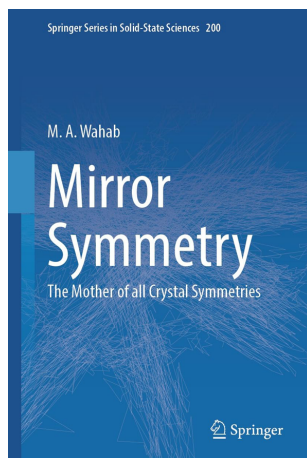
Opening *Mirror Symmetry. The Mother of all Crystal Symmetries* by M. A. Wahab one immediately finds a work that is flawed.

The idea behind the more than 220 pages of text is, as the title clearly announces, that every crystallographic symmetry operation could be reduced to a combination of mirror reflections. Sure, first-kind isometries can be obtained as a combination of second-kind isometries, whereas the opposite is not true. But none of the Sohncke groups contains second-kind (handedness-reversing) operations. For example, how the cubic point groups 23 and 432, which contain no mirror at all, could be obtained ‘by placing a set of 4 mirrors along each x , y , and z axis’ (page 31) is impossible for this reader to grasp. This should have been sufficient to question this book.

One of the main causes of the countless number of incorrect statements contained in this book is the confusion between lattice and structure, *i.e.* between the position of an atom and the position of lattice nodes. This led the same author to claim to have ‘discovered’ two new lattices and one new crystal system, simply because h.c.p. (hexagonal close-packed) and trigonal crystal structures were treated as lattices (Nespolo, 2022). This is a common mistake often found in the literature.

Ch. 1 reveals the degree of confusion which pervades the whole book. (1) A mirror as symmetry element is treated as tantamount to a light-reflecting mirror so that ‘after every successive reflection, some amount of light energy is absorbed’. (2) The diffraction patterns of all crystals are centrosymmetric. (3) The image of an object turned by 180° about its vertical axis is of opposite handedness. (4) Non-molecular crystals are always centrosymmetric. These are just a few of the incorrect statements.

Ch. 2 starts with a bombastic statement according to which the concept of fundamental and derived symmetries is understood ‘for the first time in the crystallographic history’. The chapter is essentially a graphic representation of mirrors intersecting at different angles, generating a rotation axis at their intersection. And placing another mirror perpendicular to this axis, one should obtain an inversion centre and a ‘holohedral symmetry element’. Apart from the fact that a symmetry element cannot be ‘holohedral’ (a group is), among the few examples provided we find $3/m$, which is neither centrosymmetric nor holohedral. Depending on the dimension of the space, a mirror can be a plane, a line or a point, but for the 2D case the mirror line becomes... a rotation axis! Not only is the difference between a first- and a second-kind operation misunderstood, but in a 2D space we see an in-plane rotation axis, which produces an out-of-plane rotation, *i.e.* a rotation in a 3D space which does not exist in the chosen example. But the problems do not end there. By some graphic tricks, as already in the previous publications of the same author, 2D point groups 2 and m see their respective lattices exchanged, and the same holds for the 3D point groups $mm2$ and $2/m$. How does this happen? The 2D lattices are introduced graphically, by choosing a specific, and often a special value of the interaxial angle (*e.g.* 60°), using the edges of the unit cells – whatever is their shape – as mirror lines (you find what you put in...), rotating the unit cell out of plane (in a 2D space).



Ch. 3 presents a combination of mirror reflections with a continuous mixing of dimensions (vertical lines in a 1D space, out-of-plane direction in a 2D space), primitive and non-primitive unit cells defined as containing one or more than one *atom*. We see here how catastrophic can be the consequences of the widespread misunderstanding of a lattice and a structure (Nespolo, 2019). Let me pick up just one sentence: ‘The centrosymmetric nature of the diffraction pattern and the Brillouin zone [...] forbids any form of translational symmetry, whether microscopic and macroscopic’ [sic]. To justify such a statement, repeated several times in the following chapters, the author is obliged to introduce, without defining it, a distinction between ‘translational periodicity’ and ‘translational symmetry’.

Ch. 4 is again on the combination of mirror reflections, but this time in reciprocal space. Here, we discover the presence of *atoms* at the centre of the Wigner–Seitz cell (does this occur in reciprocal space?). We also learn that X-rays contain ‘particles’ that have dual properties (and no difference with respect to electrons and neutrons). The examples presented are limited to the square lattice in 2D and the cubic lattices in 3D (should more complex cases be included?). Once again we read that ‘no translational symmetry of any kind (microscopic or macroscopic) is possible in crystals’, translations being a sort of illusion, the ‘real’ symmetry being the repetition by reflections about parallel mirrors (what about a crystal without mirrors? Such a thing does not seem to exist).

Ch. 5 presents a long series of tables with examples of interplanar spacings, which could have been replaced by a simple formula with the metric tensor. One sentence is sufficient to give an idea of the level of misunderstanding: ‘The distribution of Bragg’s planes on different Brillouin zones [...] is found to be spherically symmetric around an atom [...] The spherically symmetric nature of the diffraction patterns in reciprocal space allows the mirror, rotational and inversion symmetries while forbidding the presence of translational symmetry in crystals’.

Ch. 6 is devoted to the ‘Study of Diffraction Results of Some Cubic Crystals’ and is a series of simulated powder patterns for monoelemental and binary compounds.

Ch. 7 is explicitly devoted to the *credo* of the non-existence of translational symmetry. The existence of screw axes and glide planes is ‘ruled out’ and, even if they existed, they, as well as centred cells, would not lead to any systematic absences, a phenomenon called ‘crystallographic illusion’. How then is the occurrence of systematic absences explained? They only appear ‘due to merging of the low index planes with the next high order parallel planes’. Enantiomorphous pairs of groups (groups, not the structures crystallizing in them) exhibit the

same intensity sequences and systematic absences but ‘no suitable explanation [...] have come from anyone [...] It appears to be one of the long pending issues in crystallography’. ‘Inconsistencies and contradictions are found to be very common in the space groups’. ‘Some space groups may be mathematically legitimate, but chemically impossible’. ‘Majority of the 230 space groups proposed 200 years ago, yet to find a crystal structure’. The author is clearly unaware of the space-group list project (<https://crystalsymmetry.wordpress.com/>). Which leads to a statement about the necessity to reduce the number of space groups (the new number is not given), justified by arguments like ‘enantiomorphous pairs of space group represent the same structure’, and ‘ $I222/I2_12_12_1$ and $I23/I2_13$ each pair represents identical structures’. The very existence of space groups like $P222_1$ and $P2_12_12_1$, among others, is negated because the multiplication of matrices representing twofold rotations, *without any translational component*, leads to point group 222. The difference between point and space group is clearly not understood. Another example is ‘close packing of identical atoms cannot have 6₃ rotation axis, but can have only 3, 3 and 6’. This is unexplained, as is the following: ‘In the absence of any experimental evidence or theoretical justification in favour of screw axes and/or glide planes, their considerations appear to be simply on conjectures’.

Ch. 8 is devoted to ‘proof’ of the author’s main discovery: the existence of 16 3D space lattices and 8 3D crystal systems. I have explained the origin of this confusion previously (Nespolo, 2014).

The last chapter, ‘Fundamental Crystallography’, aims at introducing the basic notions of lattice and unit cell, and one may wonder why it comes last. It contains a set of errors, like two of the three centred unit cells in Fig. 9.2b being actually primitive, the occurrence of a mysterious ‘zero-dimensional lattice’, a hypothetical mirror line in an oblique parallelepiped, and Miller indices of points and lines, with the unnecessary restrictions to integer values.

All in all, this book cannot be recommended to anyone interested in crystallography and symmetry. The many errors rule it out for any serious study. The most intriguing aspect of this book is how it could pass a review process and be published.

References

- Nespolo, M. (2014). *Acta Cryst.* **A70**, 199–202.
 Nespolo, M. (2019). *J. Appl. Cryst.* **52**, 451–456.
 Nespolo, M. (2022). *Acta Cryst.* **A78**, 59–62.